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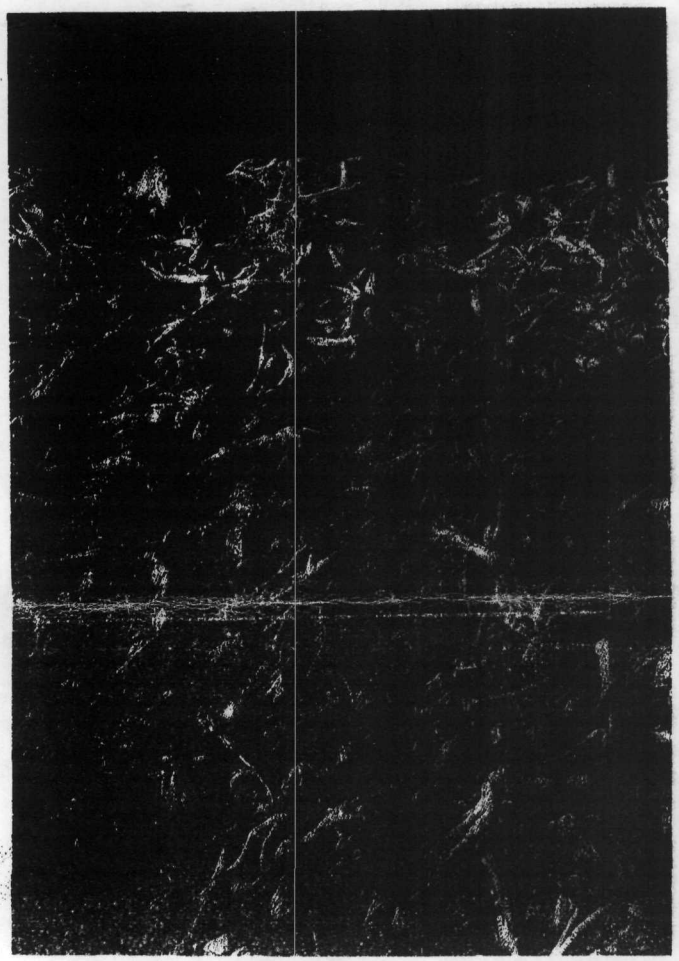
Discover Magazine
April 2006

It works!



The smell is a mélange of midsummer corpse with fried-liver overtones and a distinct fecal note. It comes from the worst stuff in the world—turkey slaughterhouse waste. Rotting heads, gnarled feet, slimy intestines, and lungs swollen with putrid gases have been trucked here from a local Butterball packager and dumped into an 80-foot-long hopper with a sickening *glorp.* In about 20 minutes, the awful mess disappears into the workings of the thermal conversion process plant in Carthage, Missouri.

The high pressure and temperature desteries all toxins like dioxin, etc.

Two hours later a much cleaner truck—an oil carrier—pulls up to the other end of the plant, and the driver attaches a hose to the truck's intake valve. One hundred fifty barrels of fuel oil, worth $12,600 wholesale, gush into the truck, headed for an oil company that will blend it with heavier fossil-fuel oils to upgrade the stock. Three tanker trucks arrive here on peak production days, loading up with 500 barrels of oil made from 270 tons of turkey guts and 20 tons of pig fat. Most of what cannot be converted into fuel oil becomes high-grade fertilizer; the rest is water clean enough to discharge into a municipal wastewater system.

For Brian Appel—and, maybe, for an energy-hungry world—it's a dream come true, better than turning straw into gold. The thermal conversion process can take material more plentiful and troublesome than straw—slaughterhouse waste, municipal sewage, old tires, mixed plastics, virtually all the wretched detritus of modern life—and make it something the world needs much more than gold: high-quality oil.

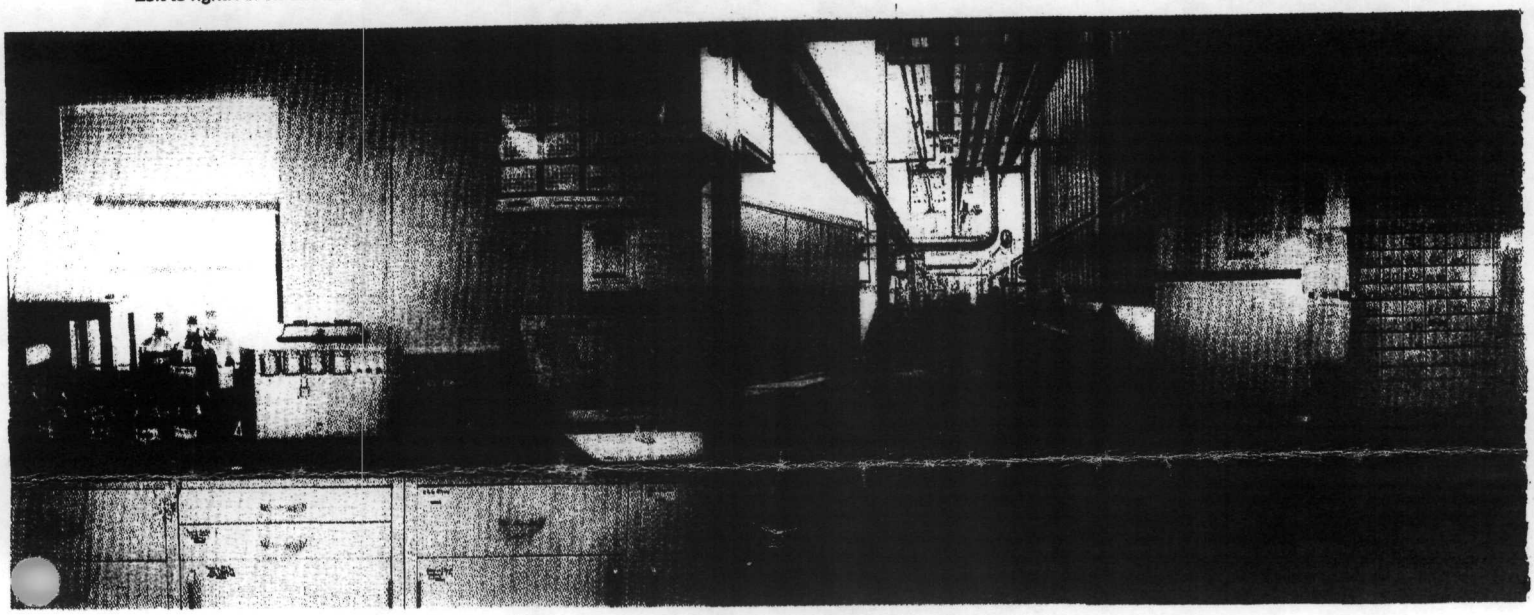
Appel, chairman and CEO of Changing World Technologies, has prodded, pushed, and sometimes bulldozed his way toward this goal for nearly a decade, and his joy is almost palpable. "This is a real plant," he says, grinning broadly. He nods at the $42 million mass of tanks, pipes, pumps, grinders, boilers, and catwalks inside a corrugated steel building. The plant is perched 100 yards from ConAgra Foods' Butterball plant, where 35,000 turkeys are butchered daily, surrendering their viscera to Appel's operation. The

Turkey guts, junked car parts, and even raw sewage go in one end

Anything

IN TO OIL

Left to right: An on-site lab checks oil and fertilizer quality a dozen times daily; some of the plant's 45 workers stroll under oil-bearing pipes; daily maintenance logs are



pig fat comes from four other midwestern ConAgra slaughterhouses. "To anybody who thinks this can't work on an industrial scale, I say, 'Come here and look.' This is the first commercial biorefinery in the world that can make oil from a variety of waste streams."

Still, Appel looks wearier than he did when *Discover* broke the news about his company's technology (see "Anything Into Oil," May 2003). Back then, when the process was still experimental, Appel predicted that the Carthage plant would crank out oil for about $15 a barrel and rack up profits from day one. But the plant was delayed by construction problems, and federal subsidies were postponed. After it started up, a foul odor angered town residents, leading to a temporary shutdown in December 2005. Production costs turned out to be $80 per barrel, meaning that for most of the plant's working life Appel has lost about $40 per barrel. As recently as last April, he feared the whole operation might implode. "There have definitely been growing pains," he says. "We have made mistakes. We were too aggressive in our earlier projections."

But now, after more than $100 million in private funding and $17 million in government grants, several hurdles have tumbled. The Carthage plant has been optimized and is expected to turn a small profit. A tax credit has leveled the playing field with other renewable fuels like biodiesel and ethanol. Appel is confident that new ozone scrubbers and other equipment will abate the odors. State officials are warily optimistic. "We are not hoping to shut them down [permanently] and take away jobs," says Connie Patterson, spokesperson for the Missouri Department of Natural Resources. "We have given them a window of opportunity to solve the problem."

Others are optimistic too. "I'm impressed," says Gabriel Miller, a New York University chemistry professor and a consultant to KeySpan Corporation, a gas and electric utility that serves New York. "The fuel that comes out is better than crude, and you don't need a refinery to use it. I think they can bring it deep into commercialization." Miller has recommended that KeySpan burn the oil in its generators.

Appel, a former Hofstra University basketball star, leans his 6-foot-5-inch frame against a counter in the company's lab and rubs his face. He says he is confident that the process can indeed solve thorny waste problems, supplement oil supplies, become an odor-free "good neighbor," and at last, become immensely lucrative.

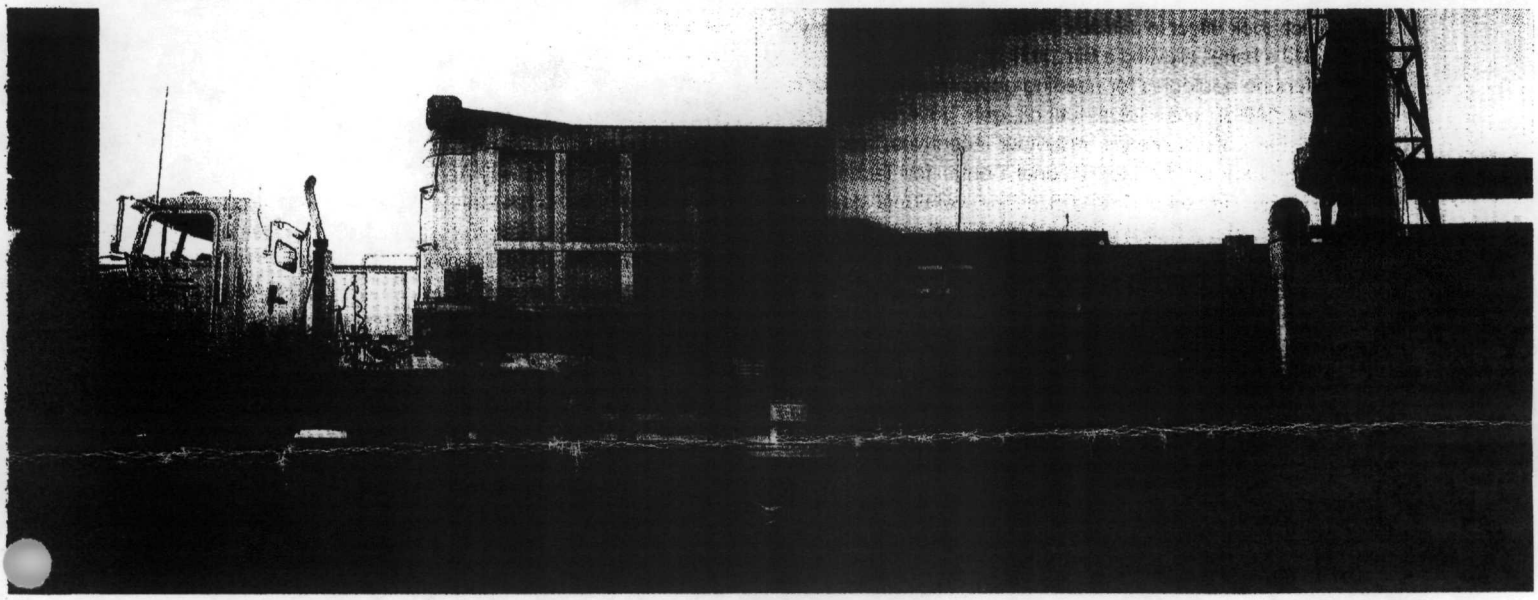
The catch? It may not happen in the United States.

Appel has shepherded development of the thermal conversion process (previously known as the thermal depolymerization process; Appel changed the unwieldy moniker last year) since 1997, building on organic-solids-into-oil research stretching back nearly a century. By 1999 he had lined up investors, hired an engineering staff, and had a pilot plant chewing through seven tons of waste daily in a Philadelphia industrial yard. Early in 2003, company officials predicted their first industrial-size plant would be steaming ahead 24/7 in Carthage by that summer. As it turned out, continuous production did not start until February 2005.

Which is surprising because at first blush, the thermal conversion process seems straightforward. The first thing a visitor sees when he steps into the loading bay is a fat pressurized pipe, which pushes the guts from the receiving hopper into a brawny grinder that chews them into pea-size bits. Dry feedstocks like tires and plastics need additional water at this stage, but offal is wet enough. A first-stage reactor breaks down the stuff with heat and pressure, after which the pressure rapidly drops, flashing off excess water and minerals. In turkeys, the minerals come mostly from bones, and these are shunted to a storage bin to be sold later as a high-calcium powdered fertilizer.

The remaining concentrated organic soup then pours into a second reaction tank—Appel says the two-stage nature of the process distinguishes it from dozens of failed single-stage waste-to-oil schemes devised over the last century—where it is heated to 500 degrees Fahrenheit and pressurized to 600 pounds per square inch. In 20 minutes, the process replicates what the deep earth does to dead plants and animals over centuries, chopping long, complex molecular chains of hydrogen and carbon into short-chain molecules. Next, the pressure and temperature drop, and the soup swirls through a centrifuge that separates any remaining water from the oil. The water, which

kept on a whiteboard; a truck is weighed before dumping turkey leftovers; the scrubber system's exhaust stack, wrapped in a steel framework, looms over the plant.



in the case of slaughterhouse waste is laden with nitrogen and amino acids, is stored to be sold as a potent liquid fertilizer (see "Garden Delights," next page). Meanwhile, the oil goes to the storage tank to await the next truck. The whole process is efficient, says Terry Adams, the company's chief technology officer: Only 15 percent of the potential energy in the feedstock is used to power the operation; 85 percent is embodied in the output of oil and other products.

The oil itself meets specification D396, a type widely used to power electrical utility generators. The oil can be sold to utilities as is, further distilled into vehicle-grade diesel and gasoline, or, via a steam process, made into hydrogen. Until last year, Appel distilled his output on-site, but he has since decided to sell the oil directly to utilities and refineries. "We just don't make enough volume to make operating our own refinery viable," he says.

So why has success been so long coming? Basically, Appel says, everything has been more complex and expensive than anyone guessed. First, the conversion process needed tweaking. Each variable—temperature, pressure, volume, tank-residence time—needs to precisely match the feedstock, which proves to be no mean feat on an industrial scale. "The really difficult thing has been finding the sweet spot in the process parameters," says Appel. "This isn't a laboratory. We have to respond to the real world of varying supply. If I get two truckloads in a row of just feathers, I need to deal with that high-protein peak. Or if I get too much blood at once, the result is too much water." The solution has been to blend disparate truckloads of stock in a holding tank, making what enters the process relatively consistent.

"Fat, fiber, protein, moisture, ash—getting those right, that's our mantra," says Jim Freiss, vice president of engineering. "Now we are able to nail the same quality every day." Freiss says he and fellow engineers Terry Adams and William Lange "have learned so much that I am very confident we can build a second plant that's optimized from the start."

Chemistry was not the only challenge. Since 2004, the federal government has subsidized biodiesel, usually made from soybeans, at $1 a gallon. It gave Appel zero for the fuel he produced from turkey guts. "It was hard to believe that a competitor could walk away with a dollar a gallon while we were excluded," Appel says. In August that hole was plugged: The fuel Appel makes, known officially as renewable diesel, received a subsidy of $1 per gallon from the Energy Policy Act

Junkyard Oil

American recyclers deftly pluck nearly all the metal from the 15 million cars junked each year, but up to 4.5 million tons of residual debris goes straight to landfills. Known as auto shredder residue, it is a virtually unrecyclable mix of at least 36 kinds of plastic, along with treated fabrics, rubber, and nylon.

Last May representatives of USCAR—a research consortium made up of DaimlerChrysler, Ford, and General Motors—along with the Argonne National Laboratory and the American Plastics Council arranged a test in which Changing World Technologies ran 3,000 pounds of the awful stuff through its Philadelphia pilot plant.

"The process is brilliant," says Candace Wheeler, a GM research scientist. "There are substances of concern in shredder residue such as PCBs, and traditional incineration of chlorinated plastics can make dioxins." But, she says, the preliminary test results indicate that the hydrolysis at the heart of the thermal conversion process breaks down the PCBs and converts the chlorine into hydrochloric acid. "No PCBs. No dioxins. No emissions," says Wheeler, noting that the principal output of the process was a "light oil" that could be used at an electric power generation plant. "It looks good from all perspectives," she says. "We think it has great potential." —B. L.

Thermal conversion is a practical large-scale method of

of 2005, which took effect in January. That boosted the company's income by $42 a barrel, allowing a slim profit of $4 a barrel.

Appel offers no apologies for needing government largesse to make money. "All oil, even fossil-fuel oil, gets government subsidies in the form of tax breaks and other incentives," he says, citing a 1998 study by the International Center for Technology Assessment showing that unsubsidized conventional gasoline would cost consumers $15 a gallon. "Before we got this, I had the only oil in the world that didn't get a subsidy."

Another hurdle: Within months after opening in February 2005, the plant smelled, and by August it had been hit by six notices of emissions violations by the Missouri Department of Natural Resources. But some in the town, which has other large food processing operations, contend the new plant was unfairly singled out. "The thing was, any odor at all was blamed on them," says Mayor Kenneth Johnson. In any case, Renewable Environmental Solutions, the subsidiary of Changing World Technologies that runs the Carthage plant, spent $2 million on biofilters, scrubbers, and other odor stoppers. Between July and late September complaints had dwindled from 23 to 5 a week, says Mark Rader, an environmental specialist with the department's southwest regional office. Nonetheless, the Department of Natural Resources issued a temporary shutdown order for the plant in December, prompting Appel and his colleagues to install more ozone scrubbers. But even critics say the persistence of a smell does not invalidate the technology. The plant is just four blocks from downtown Carthage and two blocks from residences. Building future plants in less dense areas would "make more sense," says Department of Natural Resources spokesperson Connie Patterson.

The thermal conversion process is probably the only practical large-scale method of dismantling prions, the proteins that cause mad cow disease. Although the process has never been specifically used to destroy prions, Jefferson Tester, a professor of chemical engineering at MIT, says he's confident that the proteins would be ripped apart and rendered harmless by such extreme temperatures and pressures.

Mad cow disease is thought to spread via the common American practice of feeding rendered animal parts back to animals. Appel assumed that the United States, like most modern nations, would ban the practice, creating more demand for his machinery to process leftover animal parts. In 1997 the government did ban feeding beef parts to beef cattle, but turkey and chicken cannibalism are still legal.

"We thought we would get $24 a ton for taking the waste," says Appel. "Instead, we are *paying* $30 a ton." That alone raises his production costs about $22 a barrel.

Which brings us to why Appel and his technology are likely to move to Europe. As the United States has crawled toward making its food supply safer, Europe has sprinted, eager to squelch mad cow disease as well as to stanch global warming and promote renewable energy. The result is a cornucopia of incentives for thermal conversion. Last summer Appel gave presentations to government officials and private investors throughout Europe, and the company is planning projects in Wales, Ireland, England, and Germany. Europeans are making the pilgrimage to the Carthage plant. In May Renewable Environmental Solutions ran 360 tons of beef waste through the Carthage plant for a visiting delegation from Irish Food Processors, the biggest beef operation in the British Isles. The Irish newspaper *Sunday Tribune* wrote that CEO Larry Goodman "is understood to be planning a biofuel facility . . . and hopes to have it built by next year."

The transatlantic lovefest is no wonder. In Ireland, plant operators would get an astronomical $50 per ton to haul slaughterhouse waste away, another $30 per ton in carbon dioxide emissions-reduction credits, a guaranteed price of up to $92 per barrel, and a 20-year price guarantee. "In a 500-ton-per-day plant, our production costs would be under $30 a barrel, and we could sell for about $100 a barrel," Appel says. "It's just amazing."

Only three states—California, Pennsylvania, and Virginia—have incentives that could make the process financially worthwhile for Appel. But he is encouraged by a study commissioned by an automakers' consortium showing that the thermal conversion process could be a solution to one of America's most vexing solid waste problems: the unholy mix of plastics and other leftovers from automobile metals recycling (see "Junkyard Oil," previous page). "If we do build a plant for that, it will likely be based in Michigan," Appel says.

Until recently, Appel was developing a "leave-behind strategy for us as a company and planning to set up in Europe only." Now he believes there will be some plants built in the United States as well. "I am just so happy to be making oil," he says. "I want to deploy this technology everywhere." ■

Garden Delights

Every organic gardener knows the pang of watching a neighbor blithely squirt chemical fertilizer on his vegetable garden. Sure, the schlub has no respect for nature's elegant cycles, but look at those zucchini!

Such envy could soon become history. Along with oil, the thermal conversion process drenks out a liquid fertilizer that "works a great deal like some of the instant-gratification fertilizers out there," says Jim Freiss, vice president of engineering for Changing World Technologies. Featuring 9 percent nitrogen, 1 percent phosphorus, 2 percent potash, and 16 amino acids, it is, in essence, "an organic Miracle-Gro," he says. "In the organic industry, these kinds of nutrient concentrations are unheard-of. The best that's out there is on the order of 6 percent nitrogen."

Tests on tomato and pepper plants conducted by Joseph Kloepper, professor of plant pathology at Auburn University in Alabama, confirmed the fertilizer's potency. "In my experience," he wrote in a summary paper, "it is rare to find a biological product that demonstrates such a consistent promotion of overall plant growth and root growth on two crops in two different field soils."

Fertilizer industry officials are excited as well. "Because it has been through high temperatures, there's no coliform bacteria or any of the other problems often associated with organic fertilizers such as manures," says Rai Mehta, president of Organica Biotech, a manufacturer of nonsynthetic fertilizers and pesticides. "I'm convinced there will be a large market for this." —B. L.